PUBLIC SAFETY
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WIRELESS NETWORK

Saving Lives and Property Through Improved Interoperability

Wireless Data Standards and Technology Report— Wearable Computers

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1. INTRODUCTION

Successful organizations, whether in the public or private sector, are constantly evaluating methods and technologies to improve their processes. The practical use of technology continues to be high on their list for facilitating this change. The continuing maturity and expansion of wireless computing technologies in recent times has enabled organizations of all kinds to see potential benefits.

Imagine an automobile service technician inspecting vehicles late at night. The car exhibits an unusual fault, but because the service technician is wearing a computer that can easily provide information on the appropriate tests to conduct and the likely causes of the fault, the technician can received the information while still working on the car. Or envision a civil engineer working to build a bridge across a river. Measurements and calculations needed to build the bridge can be easily transferred and downloaded at the main office. As these examples demonstrate, wearable computers allow interaction between a user and a computer while performing other tasks.

In the past, neither of the uses described above would have been feasible. The car inspection would be halted because the service technician would have to find appropriate tests in automobile manuals, and the building of the bridge would take longer because measurements and calculations would not be so easily transferred.

In the public safety community, wearable computers may offer many of the same types of benefits and efficiencies. Law enforcement personnel could extend their access to various criminal information databases and systems that are now available through mobile computer systems in their vehicles. Firefighters could have wearable technology incorporated into their protective clothing that would monitor their vital signs, such heart rate, respirations, and temperature, and report these finding to a central command and control center. The technology could also provide a foundation for in-building positioning systems and full-motion video transmissions. Emergency medical services (EMS) personnel could use wearable computers to more effectively assess and treat a victim prior to movement to an ambulance. The wearable computers would allow paramedics and emergency medical technicians to have both hands free while collecting patient information and treatment information from medical professionals. Finally, these devices could provide public safety personnel with a more expedient and effective method to create and wirelessly communicate field reports in real time.

The advantages offered by wearable computers are similar to those offered by portable computers, e.g., access to computers while away from the office or home; however, with the advancement of wearable computing technology, computing devices will provide hands-free interaction.

In addition to this introduction, this report contains the following sections:

- **Section 2, Technology Overview—**details a typical wearable computer and associated parts, describes user equipment and how users operate a wearable computer, and lists vendors involved in the wearable computing industry.

- **Section 3, Applications Overview**—discusses the advantages of wearable computers, feasible uses of the technology, and possible uses for wearable computers.

- **Section 4, Public Safety Applications and Intersections—**discusses potential uses for wearable computers in public safety, as well as ongoing efforts to introduce the technology into the public safety arena.

- **Section 5, Future Impact**—summarizes the expected impact of wearable computers.

2. TECHNOLOGY OVERVIEW

Computer technology has come a long way since the days of mainframe[1] systems. Technology has progressed from mainframes and mini-computers to desktop personal computers (PC), to notebooks/laptops, to personal digital assistants (PDA) and handheld computers, to the evolving wearable PCs.

Through recent advances, the idea of the "wearable computer" from the late 1970s and early 1980s has evolved from a cumbersome backpack-based computer system with cumbersome wireless communications into a wirelessly Internet-connected multimedia computer built into ordinary clothing or within a pair of eyeglasses. In the late 1970s, a wearable computer might have consisted of a large head-mounted cathode ray tube and separate inbound and outbound communications antennas. In the mid-1980s, it consisted of a waist-mounted television. By the late 1980s, small video cameras were housed in an eyeglass-based system. A wearable computer could now be composed of a multimedia computer, with cameras, microphones, and earphones, all built into an ordinary pair of eyeglasses. Wearable computers can now be worn constantly, without being burdensome or awkward. With the use of wearable computers, cellular telephones, personal music systems, pagers, video recorders, laptop computers, and PDAs are being replaced with one seamless apparatus with numerous functions.

A wearable computer is loosely defined in several ways. Researchers and commercial vendors alike agree that a wearable computer should be able to be used while a user is in motion or doing normal activities. Additionally, the computer should be able to be used while one or both of the user's hands are free and it should within the user's space. According to this definition, it should not be a separate object carried by the user; it should be an integral part of the user's clothing. The user should control the apparatus, and control should be maintained throughout the computer's use. Furthermore, the wearable computer should be readily available to the user, in both operation and interaction (i.e., with the use of wireless connectivity).

Figure 1 depicts the early stages of inventing the first wearable computer.

[1] Mainframe – A very large and expensive computer capable of supporting hundreds, or even thousands, of users simultaneously. In the hierarchy that starts with a simple microprocessor at the bottom and moves to supercomputers at the top, mainframes are just below supercomputers.

Figure 1
Wearable Computer of the Past[2]

The wearable computer of today is very different and could be as simple as a pair of eyeglasses, accompanied by a microphone and earphone to communicate and a wearable computer and wireless communications link attached to a vest. Figure 2 depicts an example of a wearable computer in use today.

[2] Source: Human Xtensions L.L.C.

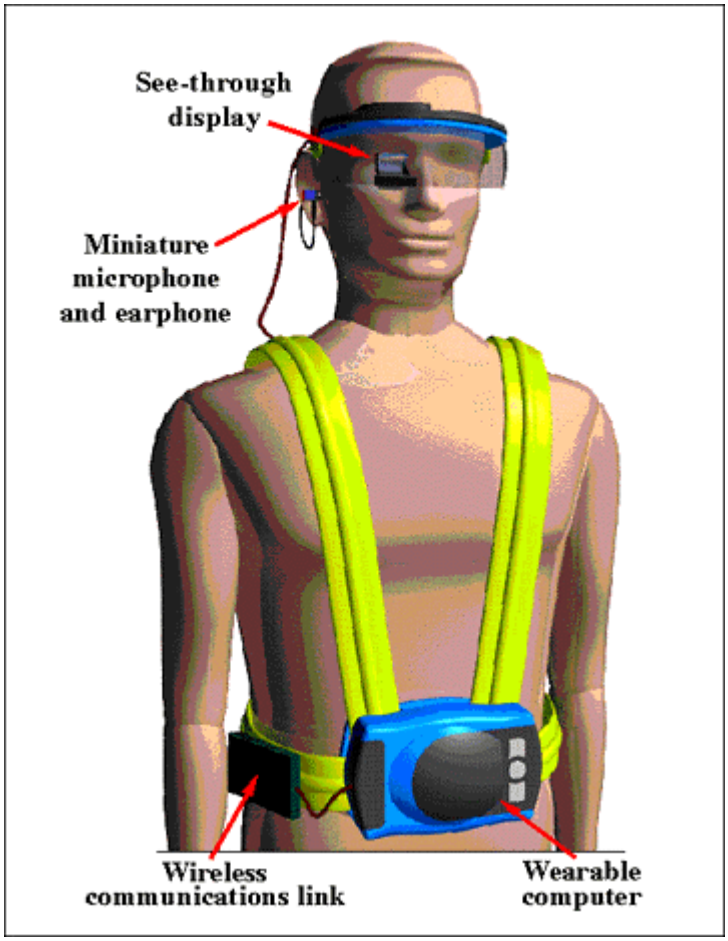

Figure 2[3]
Wearable Computer of Today

To gain a general understanding of wearable computing technology, it is important to understand the components required to construct a basic wearable computer. Although different vendors produce different designs for wearable computers, most components are similar. Typically, wearable computers use the following equipment for wireless connectivity—

- **Head Mount and Eyewear Display—**Provides a full-color viewing screen situated in front of the eye, with a viewing area resolution similar to that of a desktop monitor

- **Headset Microphone/Earphone Unit**—Provides the ability to communicate with other wireless users and/or serves as an input device to issue commands to the wearable computer

- **Wireless Communications Link**—Connects the system to the Internet or other computers via a wireless link, e.g., wireless local area network (LAN) antennas

[3] Source: Georgia Tech Wearable Technology Net Ring (http://wearables.gatech.edu/).

- **Battery Packs**—Powers the computer while it is attached to user's body

- **Operating System**—Provides the computer's operating environment—DOS, Windows CE/PocketPC, Windows 98, Windows NT/2000/XP, Linux, and UNIX are the most popular operating systems.

These systems can also include other equipment, such as barcode scanners, head-mounted cameras, touch interfaces, and arm-mounted keyboards or tablets, but these accessories are not necessarily appropriate for all markets and applications.

Wearable computers span a variety of models, such as wrist/finger, belt/head, and jewelry/watch/wallet. Belt/head worn products are typically equipped with a head-mounted display, headset microphone (for voice), and a tablet (for writing purposes). Wrist/finger worn products often include a barcode scanner, headset microphone (for voice), and touchtone interface. The needed equipment is attached to the user's body for use.

Several vendors have introduced portable multimedia appliances that bring wearable computing to those who demand the ultimate "in" technology, and numerous vendors have been involved with the evolution of wearable computers. Xybernaut/IBM, ViA, Panasonic, and Charmed Technology, among others, are involved in bringing wearable computers to the general public, as well as the public safety community.

Xybernaut, a Virginia-based commercial vendor, is already selling wearable devices to the services industries, including the public safety community. Poma™, the company's latest wearable computing offering, consists of a central processing unit with an advanced head-mounted display that delivers instant access to e-mail accounts, Internet sites, attachments, music, and games. Poma™ has a 1-inch, full-color, 640 by 480 pixel VGA viewing screen situated in front of the user's eye. The device weighs 2.8 ounces and provides a viewing area similar to that of a desktop monitor from 2 feet away. The Poma™ computer is manufactured by Hitachi and based on the Microsoft® Windows® CE operating system. It has a 128 megahertz (MHz) reduced instruction set computing processor, 32 megabyte (MB) random access memory (RAM), 32 MB read-only memory, and Compact Flash™ slot and a universal serial bus port. The estimated cost of the device is $1,499.

Figure 3[4]
Xybernaut's Poma™ Wearable Computer

[4] Source: Xybernaut (http://www.xybernaut.com).

The Massachusetts Institute of Technology (MIT) has been researching and prototyping wearable equipment. Thad Starner, now a computer science professor at Georgia Institute of Technology, founded the MIT Wearable Computing Project in 1993 as a student. Starner is now part owner of Charmed Technology Wireless Eyewear based in Santa Monica, California. MIThril is one of his company's creations.

Figure 4[5]
MIThril Wearable Computer

MIThril is a wearable computer research platform originally developed by researchers at the MIT Media Lab. The goal of the project is to develop and prototype new methods of user and computer interaction with body-worn applications. By using a variety of applications that help researchers understand the computing environment, prototype applications can be configured for different industries, such as health care and communications. The clothing-integrated design looks like a vest and houses the hardware, software, and networking equipment necessary for use. MIT has rigorously worked to accomplish this next-generation research platform for wearable computing. For additional information regarding MIT's Media Lab and ongoing research, visit the Web site at: http://www.media.mit.edu/wearables/index.html.

[5] Source: MIT (http://www.media.mit.edu/wearables/mithril/index.html).

Panasonic, a leading vendor of ruggedized notebook computers, has developed the CF-07 mini-PC with an accompanying mobile data wireless display. The CF-07 Mini PC is a Pentium III-based device that weighs 2 pounds and measures 7.87 by 3.61 by 2.05 inches. It has a 300 MHz processor, 64 MB of RAM, and a 5-Gigabyte hard drive. Its estimated price is $2,299.

Figure 5[6]
Panasonic CF-07 Minicomputer

The Mobile Data Wireless Display (MDWD), which is designed to be used with the CF-07 but also can be paired with other wirelessly enabled Panasonic Toughbooks, is an 8.4-inch SVGA touch screen that measures 8.74 by 6.38 inches. The device carries an estimated price of $1,499.

Figure 6[7]
Panasonic Mobile Data Wireless Display Device

[6] Source: Panasonic (http://www.panasonic.com/CF07.
[7] Source: Panasonic (http://www.panasonic.com/CF07.

3. APPLICATIONS OVERVIEW

Wearable computers have many advantages and are best suited for use when the following capabilities are needed—

- On-body, full-function computing
- Standard operating systems, including Windows, Linux, and UNIX
- Hands-free interaction and feet-free mobility
- Video capture, transmission/receipt, still and motion, real-time and delayed
- Integration with multilingual speech recognition and generation
- Integration with Global Positioning System (GPS)
- Integration with communications, wireless and wireline, fixed and mobile LAN/wide area network (WAN) with data, voice, and video.

Markets and industries in which wearable computing is possibly gaining a foothold include—

- Consumers—listening to music, browsing the Internet, and pursuing travel and leisure related activities
- Distribution/Warehousing—recording loading and unloading of trucks, and conducting inventory-related operations
- Education—participating in training and distance learning
- Field Service—aiding heating, ventilation, and air conditioning repair, maintenance and repair of telecommunications networks, and appliance repair
- Government/Military—providing battlefield accountability, logistics, vehicle and aircraft maintenance applications, and tracking of soldiers and supplies
- Health Care—assisting in patient care, such as monitoring vital signs and surgery, and billing applications
- Hospitality—facilitating customer service focused activities, such as conducting transactions and serving food
- Industrial/Manufacturing—monitoring and conducting data acquisition, facilitating tracking and quality control, trouble shooting

- Public Safety—aiding law enforcement, fire suppression and prevention, and emergency medical response; surveying and gathering data at crime scenes, assisting with border control, providing communications among emergency personnel, providing access to information for public safety personnel on the scene of an emergency

Figure 7[8]
Fire Fighter Accessing Critical Information

- Retail (in store)— stocking the sales floor and facilitating off-floor stockroom activities

- Transportation—aiding in vehicle and aircraft maintenance and repair, and monitoring short- and long-haul trucking, cargo, and logistics

- Utilities—assisting in maintenance and repair, meter reading, and other general operational applications.

Some related fields to the markets mentioned above are automobile, diesel and aircraft mechanics, and general maintenance mechanics. Other related fields include electronics equipment and electrical repairs, as well as health care, construction, and related inspectors. From health care to manufacturing, field workers use wearable computers for numerous applications. Current industry applications include—

- Assembly and installation

- Inspection applications—bridges (departments of transportation), nuclear power plants, and aircraft

[8] Source: ViA (http://www.via-pc.com).

- Inventory, meter reading, census, and stock or commodities trading
- Troubleshooting and fault isolation
- Maintenance and repair
- Quality control
- Operations and controls—mobile collaboration and multimedia
- Supply chain management
- Security
- Training
- Location and measurement—remote data gathering.

Wearable computer users can perform many tasks. Xybernaut is developing a computer technology that will be important to the U.S. military if the Nation goes to war in the future. Soldiers could soon have access to computer information simply by putting on fatigues and traveling into the battlefield. Xybernaut is developing MA-5, a small, fully functioning wearable computer that is a PC equivalent. Soldiers will wear the computer as part of their uniform, and the new touch-screen technology will provide them with vital information in combat, including maps and aerial views. This wearable computer includes a GPS mounted on the soldier's shoulder and a computer and video camera attached to the soldier's chest. The wearable computer is voice activated, with sensing devices, video, and telecommunications to deliver information to the wearer. By using the wearable computing technology, soldiers can receive information hands-free, while holding their weapons with their eyes on their target and ready to run for cover on the battlefield. The idea behind Xybernaut's wearable computer is not to recreate the computer but make critical computer information easier to access and use by soldiers in battle. Commanders and soldiers will be better informed and more knowledgeable, and troops on the ground can be more effective in their operations and attaining their objective. There is significant potential for public safety personnel to use this technology as well. Military facilities, including Camp Pendleton, California, and Fort Benning, Georgia, are already using wearable computing technology.

4. PUBLIC SAFETY APPLICATIONS AND INTERSECTIONS

The public safety community continues to embrace wireless data communications technologies that facilitate efficiency and promote expedient services to the citizens they serve. Wireless data equipment and services have been in use in public safety since the mid-1970 and are now widely deployed throughout many agencies across the Nation. As technology continues to evolve, so have the equipment capabilities and the available alternatives to support wireless data applications. Wearable computers with wireless connectivity are the next logical step in the evolution of devices that public safety agencies can adopt to facilitate critical access to information and communication assets and resources.

In the future, wearable computer equipment will offer additional choices to public safety officials when contemplating technology resources for field-deployed personnel in non-traditional settings. The technology may offer full and enhanced computing capabilities similar to those provided in vehicle-mounted devices without the need of the supporting vehicle.

The following information discusses several wearable computer initiatives that may positively impact the evolution and eventual adoption of wearable technologies by public safety agencies around the Nation. These initiatives are incorporating and integrating wearable technology platforms with public safety information and communications technology systems to provide enhanced informational opportunities.

4.1 National Law Enforcement and Corrections Technology Center—Southeast

The National Law Enforcement and Corrections Technology Center—Southeast (NLECTC-SE), located in Charleston, South Carolina, is one of six established centers that assess and provide technology information and assistance to the Nation's law enforcement, corrections, and criminal justice agencies. These centers are supported through a program of the U.S. Department of Justice, Office of Science and Technology.

In late 2002, NLECTC-SE initiated a research study to evaluate and baseline wearable computer technology for use by local first responders. The study envisions local responders equipped with one to two wearable computer per agency and application software to wirelessly access—

- Operational plans
- Images
- Facility blueprints
- Medical information
- Wireless networking.

The evaluation will take place in South Carolina, and the following local first responder agencies in Charleston have been selected to participate—

- City of Charleston Police and Fire Departments
- Charleston County Police, Fire, EMS and Emergency Preparedness Departments
- City of Mount Pleasant Police and Fire Departments
- City of North Charleston Police and Fire Departments
- Aviation Authority Police
- State Port Authority Police.

Xybernaut will participate as the primary hardware vendor, and Tactical Survey Group, Inc., of Crestline, California, will provide the applications software for the research study. Tactical Survey Group provides a patented interactive technology called fully spherical immersive imagery, which allows first and subsequent responders to look up, down, right, and left in a seamlessly fluid 360 degrees. Images contain embedded accurate geographic mapping based on the integrity of field-verified tactical data (see Figure 8).

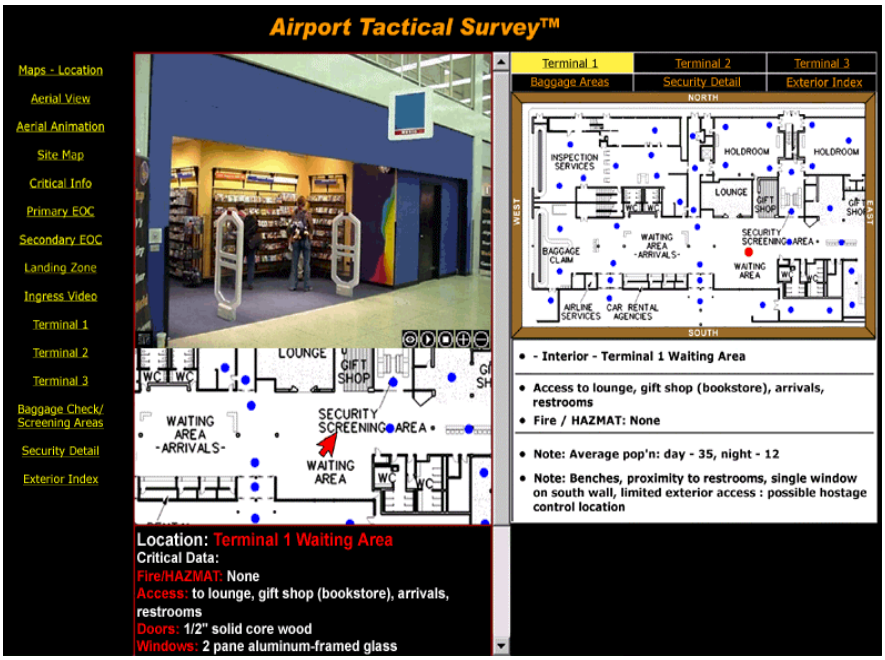

Figure 8[9]
Tactical Survey™ Application Screen

An executive committee composed of chief executives of participating agencies and a working group of representatives from each agency will govern the project. NLECTS-SE and Xybernaut will manage the project.

4.2 U.S. Army Soldier Systems Center—Digital MP System

In late 2000, the 91st Detachment of Military Police (MP) at Fort Polk, Louisiana, field-tested the Army's new "Digital MP System," developed by the U.S. Army Soldier Systems Center in Natick, Massachusetts. MP officers wore eyeglass-mounted miniature cameras providing

[9] Source: http://www.tacticalsurveygroup.com/images/level2_screen.gif.

"streaming video" to their partners. The eyeglasses also supported viewing screens that permit MPs to check the faces of suspects they had stopped against digital mug shots of known offenders. The Digital MP system is a durable, lightweight, wearable communications and information management system designed to help carry out reconnaissance, checkpoint security, anti-terrorism operations, and other MP missions.

The Digital MP system, which incorporates a wearable computer developed by ViA Inc. and other components from MicroOptical Corporation and Honeywell Inc., is tailored to meet the mission requirements of the MP soldier. The system features a hands-free, voice-operated interface and a battery that provides daylong power on a single charge. The system features peripherals such as—

- An audiovisual system with built-in miniature camera for face recognition and image display mounted in normal sized eyeglass frames
- A noise-canceling microphone and bone-conduction microphone/earphone for voice recognition, also incorporated in the eyeglass frame
- A large pocket-sized "military e-book," readable even in strong sunlight or pale starlight (with night vision goggles) that emits no light to give away a soldier's position
- An electronic glove that can function like a computer mouse with the e-book and translate hand signals into words on other soldiers' eyeglass-mounted viewers.

The Digital MP system can connect a team of MPs wirelessly and in ways never before possible. As mentioned above, the eyeglass-mounted camera provides streaming video, which can transmit images between multiple users of the system even when they are not located together or looking at the same content.

Another feature of the system allows MPS making a traffic stop or staffing a checkpoint to take live videos that can then be checked against automated digital imaging (mug shot) systems. This capability can alert the MP if the person stopped has a criminal record. On a deployment, the system can warn MPs if they are confronting a suspected terrorist or war criminal.

An MP using the system in a patrol environment can use the e-book capability to quickly help others locate what he or she sees. Using traditional methods, the soldier would be required to plot coordinates on a paper map, call an operations center on the radio, have another soldier plot the coordinates on another map, and then have the information relayed to other resources. With the Digital MP system, an icon is placed on the map, sent to the operations center, and is immediately available to other similarly enabled MPs.

The Digital MP system also incorporates an electronic glove, which enables MPs separated by thick woods, buildings, or darkness to communicate silently with the familiar hand signals. The adapted Nomex flight glove contains bend sensors in each finger and in the wrist,

pressure sensors in the index and middle fingertips, and 2-degree tilt sensors. It renders preprogrammed gestures as words in fellow MPs' eyeglass display monitors. The glove works when the signaler has no line-of-sight communication with fellow users and does not want to give away his position by speaking. The glove also functions like a mouse with the e-book, guiding the cursor with the tilt sensor and reading the pressure sensors as right and left clicks. The glove capability can override the voice-operated system when silent operations are required.

The Digital MP system can also be programmed to continuously translate speech from English to another language and vice versa, with only a 5-second delay. It can translate Spanish, Korean, Arabic, German, French, Italian, Portuguese, Dutch, Thai, and Turkish.

4.3 San Diego Police Department

In August 2002, the San Diego Police Department initiated a pilot program that deployed semi-wearable PCs to motorcycle officers. The pilot program is being conducted with CDCE, a mobile integrator in Yorba Linda, California. The technology allows the officers to use a touch screen tablet to enter and access computerized information wirelessly without returning to their motorcycles or relying upon voice communications with a dispatcher. The system provides motorcycle-mounted officers access to the same information databases and resources as other officers in patrol cars.

Motorcycle officers participating in the pilot are using the Panasonic MDWD and Toughbook CF-07 Mini PC to process traffic violations. When they stop a vehicle, they can take the ruggedized 1.5-pound MDWD to the violator's vehicle window while leaving the mini PC at the motorcycle.

The wireless display unit communicates with the mini-PC base system via a proprietary broadband wireless system that operates up to 300 feet away from the motorcycle. The mini-PC base system communicates with the city's public safety computer systems using a wireless WAN. The wireless technology enables officers to query the city's public safety computer systems for driver license status and to enter complete citation information using the remote MDWD. This capability increases the officer's efficiency and allows the report or citation information to be more readily available.

4.4 Essex County Correctional Facility—Middleton, Massachusetts

In most correctional facilities, corrections officers can physically patrol the cell areas or use video cameras to monitor inmates and the facility. In November 2002, the Essex County Correctional Facility began using two wearable computers to augment existing technology systems that help to maintain order and spot trouble within the facility.

Essex County has deployed wearable wireless computers worn on the waist that weigh about 2.5 pounds and include a foldable screen. These devices are linked to the facility's new video monitoring system, which enables an officer on the floor to monitor other parts of the 10-building complex and its 1,100 inmates. The connectivity to the video system allows responding

officers to view an incident scene before they arrive and allows them to coordinate what they do before they enter the building.

The wearable computers are also used to record and retrieve information about inmates and incidents. In addition, they provide a report writing capability that enables corrections officers to electronically submit required reports subsequent to an event or incident. In the past, reporting writing usually required an officer to leave a colleague alone on the jail floor and use the nearest computer to enter the information. Plans are being considered to provide access to the medical records of prisoners and guards for instant retrieval and transmission to the infirmary or hospital emergency rooms.

The wearable systems can also support small video cameras that can be attached to record any events that might generate a prisoner complaint or a need for subsequent administrative review. The recorded session could be used as proof in any hearing that might follow a complaint from a prisoner, or as a training video for other officers.

The wearable computers are based on 500 MHz Pentium processors and manufactured by Xybernaut of Fairfax, Virginia.

Figure 9[10]
Essex County Correctional Wearable System

[10] Source: http://www.nytimes.com/2002/11/14/technology/circuits/14pris.html.

5. FUTURE IMPACT OF WEARABLE COMPUTERS

The future of wearable computers is promising. Use of wearable computers continues to grow worldwide, and advances in the technology are made every day. Hopefully, the prices of these devices will continue to become more reasonable as companies and individuals have a more vested interest in the future of wearable computers.

New applications and new markets are stimulating growth in the use of wearable computers. Gartner Group has estimated that 137 million workers worldwide are mobile. IDC forecasts that the market for commercial wearable computers in the United States is currently more than $600 million. This estimate does not include consumer-oriented systems or systems sold outside of the United States. Gartner also predicts that from 2006 to 2011, "always on" wearable technology devices will become a mainstream technology and that by 2007, 60 percent of European and U.S. populations ages 15 to 50 will use a device daily for 6 hours or more. Gartner estimates that this number will increase to 75 percent by 2010.

Technology market research firm Venture Development Corporation[11] (VDC) reports that the wearable market, led by military, medical, public safety, and sports users, will reach a value of more than $100 million in 2002 and grow to more than $563 million by 2006. The emergence of "smart fabrics" or interactive textile wearable products will lead to a viable market by 2006.

As with many commercially available technologies, the public safety community will likely continue to evaluate and adopt wearable technologies in the future. This adoption will occur as public safety technology vendors incorporate wearable platforms into their existing offerings and public safety services identify additional beneficial opportunities for use. Presently, public safety agencies have several available mobile platforms to extend critical information and communications services to field-deployed personnel.

The advent of PDA and PocketPC devices that will support mainstream public safety applications may diminish the need for wearable computers especially if the cost of the wearable devices continues to be significantly higher than that of handheld devices. However, the continued advancement of the wearable technologies, coupled with enhanced miniaturization of components and their incorporation into protective clothing and uniform equipment, may provide the catalyst for public safety to seriously consider adoption of this computing platform.

[11] VDC is a technology market research and strategy firm that has developed a highly successful methodology for realistically forecasting and analyzing highly dynamic technology markets.

Appendix A—Acronyms

APPENDIX A—ACRONYMS

EMS	Emergency Medical Services
GPS	Global Positioning System
LAN	Local Area Network
MB	Megabyte
MDWD	Mobile Data Wireless Display
MHz	Megahertz
MIT	Massachusetts Institute of Technology
MP	Military Police
NLECTC-SE	National Law Enforcement and Corrections Technology Center—Southeast
PC	Personal Computer
PDA	Personal Digital Assistant
RAM	Random Access Memory
VDC	Venture Development Corporation
WAN	Wide Area Network